MONIEZIA, A GENUS OF CESTODE WORMS AND THE PROPOSED REDUCTION OF ITS SPECIES TO THREE

By E. Leonard Taylor

Of the Veterinary Laboratory of the British Ministry of Agriculture and Fisheries

The work on which this paper is based was done in the laboratory of the Zoological Division of the Bureau of Animal Industry, United States Department of Agriculture, at the suggestion of Dr. Maurice C. Hall. The material and facilities of the helminthological collection of the United States National Museum were put at the disposal of the writer for this work.

The question of the number of valid species in the genus *Moniezia* was taken up by G. Theiler (in 1924) at the Liverpool School of Tropical Medicine. She found a wide range of variation in the segments of a single strobila, and came to the conclusion that only four species could be allowed, namely, *M. expansa*, *M. trigonophora*, *M. benedeni*, and *M. alba*, and of these four she expresses a doubt as to the validity of the two species *M. trigonophora* and *M. alba*. Two other species, *M. rugosa* and *M. amphibia*, are placed as species inquirendae, pending a reexamination of the original material. As this genus is of considerable economic importance it seemed particularly desirable to check over the above work.

It is much easier to divide a group of individuals into a number of species according to their various dissimilarities than to show satisfactorily that a number of dissimilar individuals really belong to one and the same species, and that their variations are not of specific rank. And it is indeed impossible, from a mere morphological study, to prove beyond doubt that the variations occurring do not go beyond the limits of one species. Proof could only be found by studying the variations occurring in the progeny of one parent worm, but our complete ignorance of the life cycle of worms of the genus *Moniezia* unfortunately renders this impossible.

The method followed in collecting data for this paper has been the same as that used by G. Theiler; fresh worms have been taken from sheep and cattle at the abattoirs, and complete specimens stained and

No. 2754.—Proceedings U. S. National Museum, Vol. 74, Art. 9
2612—28

mounted *in toto* and examined from head to terminal segment. It is no small task to examine a large cestode in this way, for the number of segments present in each worm examined varied between 1,136 and 2,118 in the *M. expansa* group, and 758 and 1,462 in the *M. planissima* group. Twenty complete worms, selected because they showed the most varied naked eye appearance, and as many more portions of worms were examined in this way.

It is proposed to mention a number of the characters used in definitions of the species of the genus *Moniezia*, and to show that extremes of size and shape are joined by a more or less regular series of intermediate modifications.

In examining the descriptions of members of this genus the writer has found only six definite specific characters, which may be stated as follows: The interproglottidal glands may be absent, as in *M. alba* (1). When present they may be of the linear type, as in *M. planissima* (2), or they may be of the saccular type, as in *M. expansa* (3), or, according to Sauter, both types may be present in one worm, as in *M. conjugens* (4). The testes instead of being in one band may be arranged in two triangular areas, as in *M. trigonophora* (5). The uterine folds usually pass only on the dorsal side of the longitudinal excretory vessels, but they may pass both dorsally and ventrally, as in *M. pallida* (6).

Apart from these six characters, specific identity appears to depend upon a number of more or less slight variations, among which the following may be mentioned as the more important:

1. Shape and direction of the suckers, and shape of head.
2. Color and translucency of the strobila.
3. Length of the worm and the number of segments present in the strobila.
4. Size of the largest segment.
5. Width of the head.
6. Length of the neck.
7. Distance from the head at which the first genital primordia appear.
8. Distance from the head at which the first testes may be seen.
9. Number of testes present in each segment.
10. Interproglottidal glands, their number to the segment in the *M. expansa* group, and their length in the *M. planissima* group; and whether distinct or only faintly visible.
11. Position of the genital pore.
12. Size of the eggs.

1. From the study of the writer's material and of descriptions and drawings of the various species, the differences in the shape of the head seem to be no more than could easily be explained by the plastic

nature of this structure; and the same remark applies to the relative position and direction of the suckers.

2. Variations in color are only slight, and appear to depend entirely upon the age of the worm and whether the segments have reached the large intestines; older worms are yellower and segments in the large intestine become stained by the ingesta.

The variation in the translucency of the strobila is not very great and seems to be of no value. Characters which depend upon such comparative terms as "a little more" or "a little less than some other species" are obviously of slight value for definition, and in several species the shape of head and suckers, and the color and translucency of the strobila are so described.

Characters which are a matter of numbers, and of linear measurement can be dealt with in a more convincing manner, and there are given below the two extremes of size or number of various structures by a series of all the intermediate measurements. If any of the characters are valuable, and if there are two or more species present, some evidence of their presence should be seen in a marked discontinuity in the chain or intermediate variations.

3. *The number of segments in the strobila.* The number of segments were counted in seventeen strobila of the *M. expansa* group and the two extreme variations found to be 1136 and 2118 segments for each strobila: the intermediate worms joined these two in the following way, the figures representing the number of segments present in each worm: 1136, 1158, 1233, 1385, 1392, 1443, 1463, 1490, 1511, 1565, 1579, 1581, 1886, 1918, 1944, 1969, and 2118. It will be noticed that the only considerable gap is between 1581 and 1886, the remainder of the series running evenly.

4. Measurements in width of the largest segment taken from nineteen specimens of the *M. expansa* group were found to vary between 2 mm. and 8 mm., the list of measurements arranged in order being as follows, the numbers representing millimeters: 2, 2.8, 3, 4, 4.5, 4.8, 5, 5, 5, 5.5, 6, 6, 6, 6.5, 7, 7, 7, 7.5, 8. In this series there is no marked discontinuity, but a regular increase in size, the majority of the worms being of a medium size.

5. Measurements in width of head taken from seventeen specimens of the *M. expansa* group showed a variation between 0.42 mm. and 0.75 mm., the whole series, given in millimeters, being as follows: 0.42, 0.45, 0.48, 0.495, 0.495, 0.495, 0.515, 0.525, 0.57, 0.57, 0.585, 0.60, 0.615, 0.63, 0.645, 0.675, 0.75. The variation in this series shows no marked discontinuity.

6. Measurements taken from seventeen specimens of the *M. expansa* group showed a variation in length of neck between 0.15 mm. and 1.875 mm., the series of measurements in millimeters being as follows:

0.15, 0.30, 0.30, 0.36, 0.375, 0.405, 0.45, 0.75, 0.8, 0.90, 1.05, 1.15, 1.2, 1.5, 1.575, 1.59, 1.875. For the most part this series shows a uniform increase in size, the three greatest gaps being from 0.45 to 0.75, 1.2 to 1.5, and 1.59 to 1.875.

7. The distance from the head at which the first genital primordia make their appearance. In eighteen specimens of the *M. expansa* group this point was found to vary between the 150th and the 424th segment, the whole series being as follows, the figures representing the number of the segment from the head: 150, 155, 160, 180, 290, 300, 300, 316, 320, 320, 340, 350, 390, 400, 400, 410, 415, 424. There is a discontinuity of the series between 180 and 290, the remainder being very even.

8. The distance from the head at which the first testes may be seen. Of seventeen specimens of the *M. expansa* group this was found to vary between the 390th and the 1018th segment, the complete series being as follows, the numbers representing the number of the segments from the head: 390, 495, 672, 690, 697, 700, 710, 712, 720, 750, 761, 767, 801, 852, 910, 937, 1018. The variation in this series showed no marked discontinuity.

9. The number of testes was counted in a few segments of twelve specimens of the *M. expansa* group, and the greatest variation in any one worm was found to be between the 198 and 260 testes per segment, and the greatest variation within the twelve was found to be between 109 and 296. The average number of testes of each segment in each of twelve specimens of the *M. expansa* group formed the following series, each number representing the average number of testes to the segment: 120, 124, 147, 200, 202, 211, 215, 229, 240, 247, 247, 284.

The size of the testes also showed considerable variation, the greatest variation observed in one individual worm being between 0.07 and 0.15 mm. in diameter, and in the group of twelve worms examined the greatest variation observed was between 0.035 and 0.15 mm. The average diameter in millimeters of the testes in sixteen specimens of the *M. expansa* group was as follows: 0.040, 0.050, 0.052, 0.055, 0.060, 0.065, 0.067, 0.067, 0.075, 0.075, 0.077, 0.085, 0.087, 0.110, 0.110, 0.115.

10. The number of interproglottidal glands per segment. Of 15 specimens of the *M. expansa* group in which counts were made, the average number of glands to the segment was found to vary between 0.5 and 64 glands to the segment. The complete series of counts were as follows, each number representing the average number of glands present to the segment: 0.5, 6, 8, 9, 10, 11, 14, 16, 20, 40, 45, 54, 58, 60, 64. The greatest variation observed in one individual was between no gland and 42 glands, and the greatest varia-

tion in the group of 15 worms was between no gland and 76 glands to the segment.

No attempt was made to count the glands in very young segments, where they were insufficiently formed to be easily recognizable. It was observed that in some worms the number of glands was smaller at the anterior end, increasing toward the terminal segment; while the reverse was true of other worms, and some presented a middle part of the strobila with fewer glands than were seen toward the two extremities. One worm showed only occasional glands in the first 1,600 segments, there being only 303 glands in 777 segments mature enough to show formed glands.

11. The position of the genital pore. According to the observations made, the position of the genital pore varies only with the state of the muscular contraction of a segment and with the overlap of the previous segment, which may cause it to appear anterior to the middle but never posterior. It seems to be a very poor specific character.

12. Unfortunately no measurements were made of the eggs before staining and mounting the material studied, so that it is impossible to treat with these measurements as with the others.

With reference to the *M. planissima* type, showing the interproglottidal glands arranged in the form of a band, it was possible to obtain only four whole worms and five portions; these were subjected to the same kind of examination as that described for the *M. expansa* group and gave parallel results, the specimens showing great variation between segments in the same worm, and a greater, but not very much greater, variation between segments from different worms.

It was not possible to find a constant relationship between any of the various characters dealt with above, and the gradual series of variations shown in the measurements and counts given would suggest very strongly that the characters on which the determination of some species of *Moniezia* depends are no more than individual variations and have no specific value.

Four species call for special mention. *M. trigonophora*, as mentioned above, is distinguished by the grouping of the testes into two triangular masses. This character seems to be a very variable one and of seventeen specimens of the *M. expansa* group examined, only three were found which did not possess some segments in which this was shown. Two worms clearly showed the grouping in every segment and twelve worms showed the two types, some segments with the triangular grouping, and some with the band of testes running across the segment. If the number of segments showing the triangular grouping are expressed as a percentage of all the segments

in which testes were plainly seen the series reads as follows, each number representing so many per cent: 0, 0, 0, 0.5, 2, 4, 5, 8, 10, 22, 39, 59, 60, 81, 82, 100, 100.

In this connection Stiles and Hassall's types of this species were examined, and many segments were found in which the triangular arrangement of testes is by no means distinct. As has been shown by G. Theiler, *M. planissima* may also show this arrangement of testes in some segments, and in this species I have found it to be present in as many as 215 of 335 segments showing recognizable testes. It is therefore concluded that the triangular grouping of the testes is not a good specific character.

Moniezia alba has been distinguished by the absence of the interproglottidal glands. As reported by Theiler, these glands are sometimes very indistinct, or even absent; and as shown in the writer's observation there may be actually more segments without these glands than with them. In this connection Perroncito's type material was examined. The differentiation of the stain is poor in these specimens, which may account for the fact that it was impossible to find definite interproglottidal glands, but in Stiles and Hassall's original *M. alba* material it was possible to find satisfactory assurance that glands of the linear type were present in some of the segments. Doctor Hassall has informed the writer that at the time of the writing of the joint paper by Stiles and Hassall some doubt was entertained as to the validity of this species. It therefore seems most probable that the absence of interproglottidal glands is not a good specific character.

Moniezia conjugens has been described by Sauter as showing both types of interproglottidal glands in the same worm. The writer has not found any specimens of this kind, but has seen in *M. planissima* small portions of gland separated from the main strip and having the appearance of the saccular type when examined under a low magnification. However, when greatly magnified these glands are seen to be of the linear type as there is no evidence of any grouping of the gland cells round blind sacs. It is possible that Sauter overlooked this point but it seems preferable to leave his species, pending a reexamination of the original material, as a species inquirenda.

Moniezia pallida from the horse has recently been described by Monnig who kindly sent some of his type material to the Bureau of Animal Industry section of the United States National Museum Collection. The distinctive feature of this species is that the folds of the uterus pass ventrally, as well as dorsally, beyond the longitudinal excretory vessels. The writer sectioned several segments of this material and in each place found this disposition of the uterus to exist. He also sectioned six segments of *M. expansa* and four of *M. planissima*, each segment from a different worm, and found in

every section that the folds of the uterus passed only dorsally to the longitudinal excretory vessels, occasionally sending a short fold back from the lateral fields ventral to the vessels, but the folds never passing into the lateral fields by this way. It therefore seems probable that *M. pallida* is a valid species.

SUMMARY AND CONCLUSIONS

1. A number of complete specimens of *Moniezia* of the two groups *M. expansa* and *M. planissima* have been stained and examined *in toto* and a remarkable variation found to occur between the different segments in one worm. Although the range of variation is more marked when different worms are compared, it has been shown that extremes of size and shape and of the number of various parts are linked by a series of intermediates which shows no marked discontinuity. It therefore must be concluded that these characters are of no specific value.

The range of variation in the material examined does not completely cover the extremes which have been recorded in the description of the various species, but it is highly probable that the examination of more material would extend it to include these also.

2. Type material of *M. alba* and *M. trigonophora* has been re-examined and it is proposed to place these two species in synonomy.

3. The validity of the species *M. conjugens* is questioned, as specimens of *M. planissima* which at first appeared to possess both the linear and the saccular type of interproglottidal gland were shown on closer examination to have only the linear type.

4. Type material of *M. pallida* has been re-examined and Monnig's observations on the passage of the uterine folds ventral as well as dorsal to the longitudinal excretory vessels have been verified.

5. This work has verified the work done by G. Theiler, and it is proposed to synonymise the specific names as follows:

(*a*) *Moniezia expansa* (Rudolphi, 1810) Blanchard, 1891.

Synonyms:

M. oblongiceps Stiles and Hassall, 1893.
M. trigonophora Stiles and Hassall in Stiles, 1892.
M. minima Marotel, 1912.
M. nullicollis (Moniez, 1891) Blanchard, 1891.

(*b*) *Moniezia benedeni* (Moniez, 1879), Blanchard, 1891.

Synonyms:

M. planissima Stiles and Hassall, 1893.
M. translucida Jenkins, 1923.
M. alba (Perroncito, 1878) Blanchard, 1891.
M. triangularis Marotel, 1913.
M. latifrons Sauter, 1917.
M. crassicollis Sauter, 1917.

M. parva Sauter, 1917.
M. neumanni (Moniez, 1891) Blanchard, 1891.
M. pellucida Blei, 1920.
M. amphibia v. Linstow, 1901.
M. chappuisi Baer, 1923.

6. Three species are validated:
M. expansa (Rudolphi, 1810) Blanchard, 1891.
M. benedeni (Moniez, 1874) Blanchard, 1891.
M. pallida Monnig, 1926.

7. Two species remain as species inquirendae:
M. rugosa (Diesing, 1850) Luehe, 1895.
M. conjugens Sauter, 1917.

BIBLIOGRAPHY

Baer, J. G.
1926—Contributions to the helminth-fauna of South Africa. 11. and 12. Rep. Dir. Vet. Educ. and Research, Dept. Agri., Union of South Africa, Pretoria, pp. 63–136, 1 map, figs. 1–43.
1927—Monographie des cestodes de la famille Anoplocephalidae. Suppl. X an Bull. biol. de France et de Belgique, Paris, 243 pp., 43 figs., 4 pls.

Douthitt, H.
1915—Studies on the scetode family Anoplocephalidae. Illinois, Biol. Monogr., Urbana, vol. 1, pp. 353–446, pls. 1–6, figs. 1–49.

Hall, M. C.
1927—Parasites and parasitic diseases of sheep. Farmers' Bull. 1330, U. S. Dept. Agri., Washington, 35 pp., figs. 1–34.

Jenkins, J. R. W.
1923—On a new species of *Moniezia* from the sheep, *Ovis aries*. Ann. Applied Biol., London, vol. 10, pp. 276–286, figs. 1–2, pl. 15.

Sauter, K.
1917—Beiträge zur Anatomie, Histologie, Entwicklungsgeschichte und Systematik der Rindertänien. (Thesis, München), 79 pp., 10 pls., 29 figs. Kulmbach.

Stiles, C. W.
1892—Sur le *Taenia expansa* Rudolphi. Compt. rend. Soc. de biol., Paris, ser. 9, vol. 4, pp. 665–666.
1896—A revision of the adult tapeworms of hares and rabbits. Proc. U. S. Nat. Mus., Washington, vol. 19, pp. 145–235, pls. 5–25.

Stiles, C. W.; and Hassall, A.
1893—A revision of the adult cestodes of cattle, sheep, and allied animals. Bull. 4, Bur. Anim. Indust., U. S. Dept. Agri., Washington, 134 pp., pls. 1–16.

Theiler, G.
1924—On the classification of the cestode genus *Moniezia* (Blanchard, 1891). Ann. Trop. Med. and Parasitol., Liverpool and London, vol. 18, pp. 109–123, figs. 1–12.

EXPLANATION OF PLATES

PLATE 1

FIGS. 1, 2, 3, 4. Examples of variation in head and neck of *Moniezia expansa*. (All four are of the same magnification.)

5, 6. Two parts of one individual *Moniezia expansa* showing different arrangements of testes.

PLATE 2

FIGS. 7, 8, 9. Three parts of one individual *Moniezia expansa* showing varying arrangements of testes and scarcity of interproglottidal glands. Only two glands are present in all the segments shown in Figures 8 and 9, and in Figure 7 there are no glands at all.

10. One part of one individual *Moniezia expansa* showing a variation in the number of interproglottidal glands present in different parts of the strobila.

PLATE 3

FIGS. 11, 14. Two parts of one individual *Moniezia expansa* showing a variation in the number of interproglottidal glands present in different parts of the strobila.

12, 15. Two parts of one individual *Moniezia expansa* showing a considerable variation in the number of interproglottidal glands in the two different parts of the strobila.

13. Part of one individual specimen of *Moniezia planissima* showing various arrangements of testes. In Figure 24, the linear type of interproglottidal gland is seen broken into various lengths, the shortest of which might be mistaken for the saccular type of gland.

PLATE 4

FIGS. 16, 17, 18. Three parts of one individual *Moniezia expansa* showing variation in the arrangement of the testes.

19. Parts of one individual specimen of *Moniezia expansa* showing large numbers of interproglottidal glands. The individual shown in Figures 10 and 11 is intermediate between these and the worms shown in Figures 7, 8, 9, 15, 16, and 17.

PLATE 5

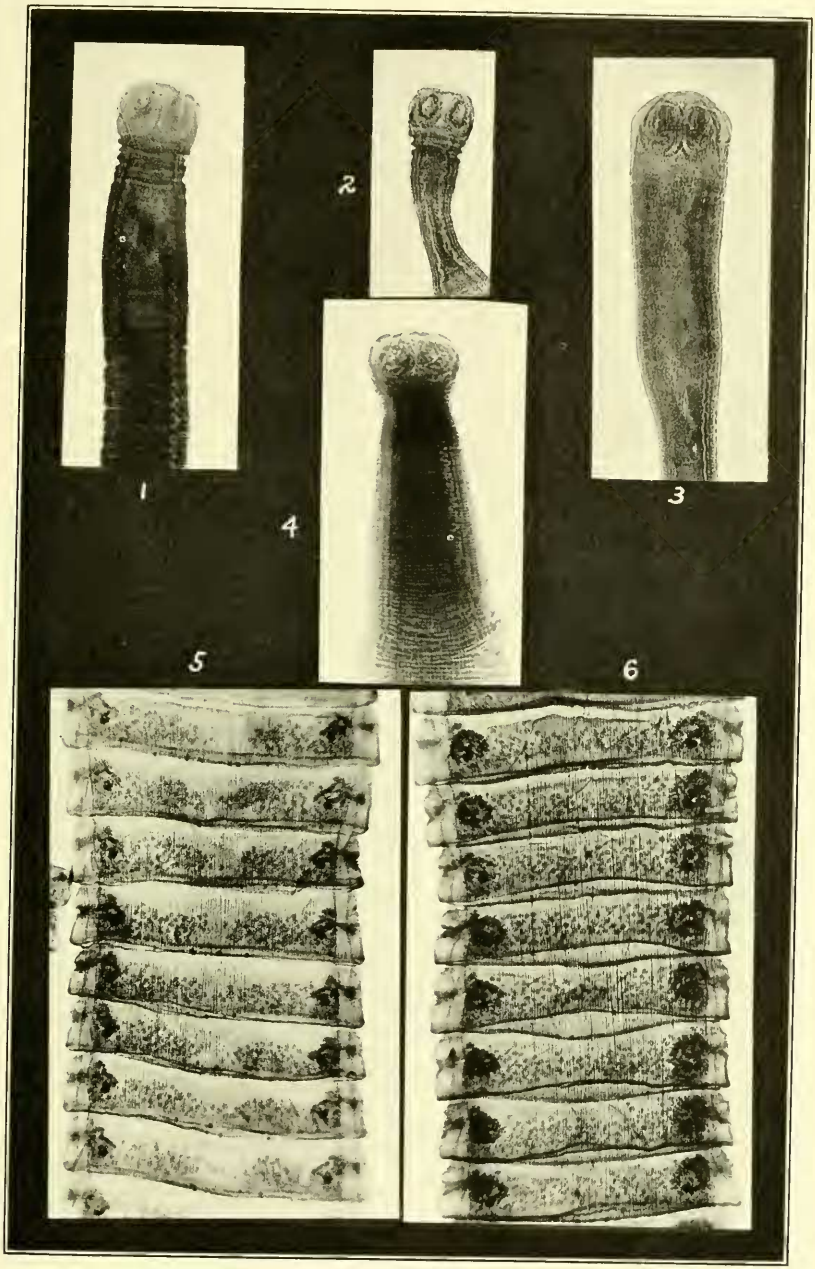
FIGS. 20, 21. Parts of two individual specimens of *Moniezia planissima* showing the various arrangements of testes. In Figure 24 the linear type of interproglottidal gland is seen broken into various lengths, the shortest of which might be mistaken for the saccular type of gland.

22, 24. Two parts of one individual *Moniezia expansa* showing variation in the shape of the segments and a very crowded arrangement of interproglottidal glands.

23. Parts of one individual specimen of *Moniezia expansa* showing large numbers of interproglottidal glands. The individual shown in Figures 10 and 11 is intermediate between these and the worms shown in Figures 7, 8, 9, 15, 16, and 17.

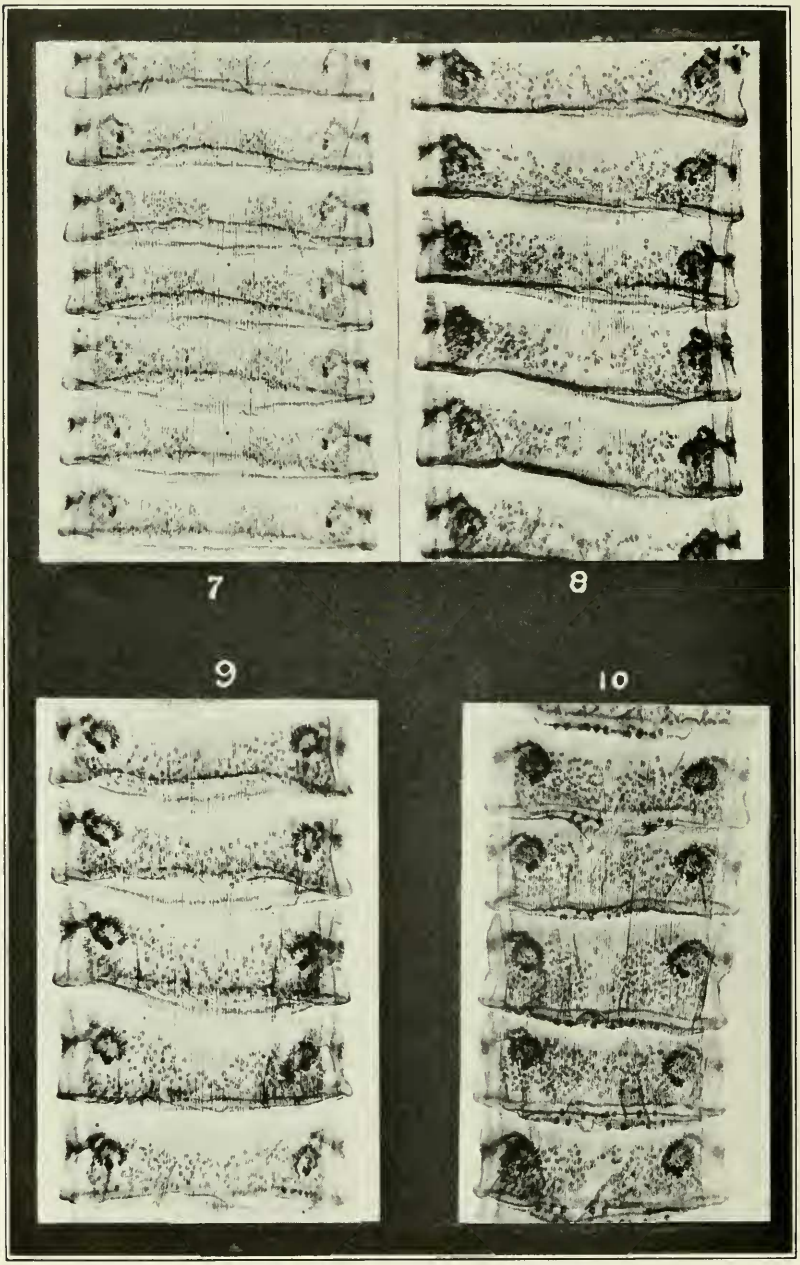
All the figures of portions of strobila are of the same magnification

○



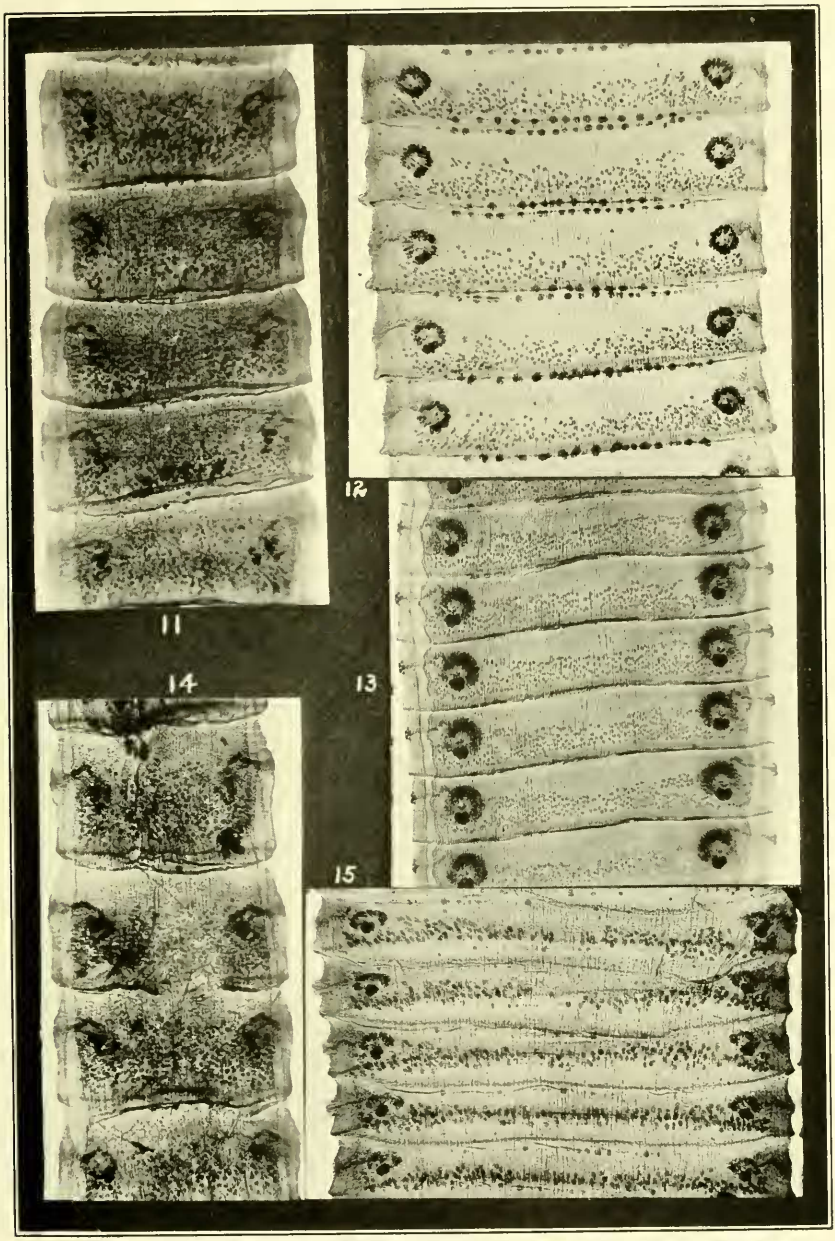
VARIATIONS IN MONIEZIA EXPANSA

FOR EXPLANATION OF PLATE SEE PAGE 9



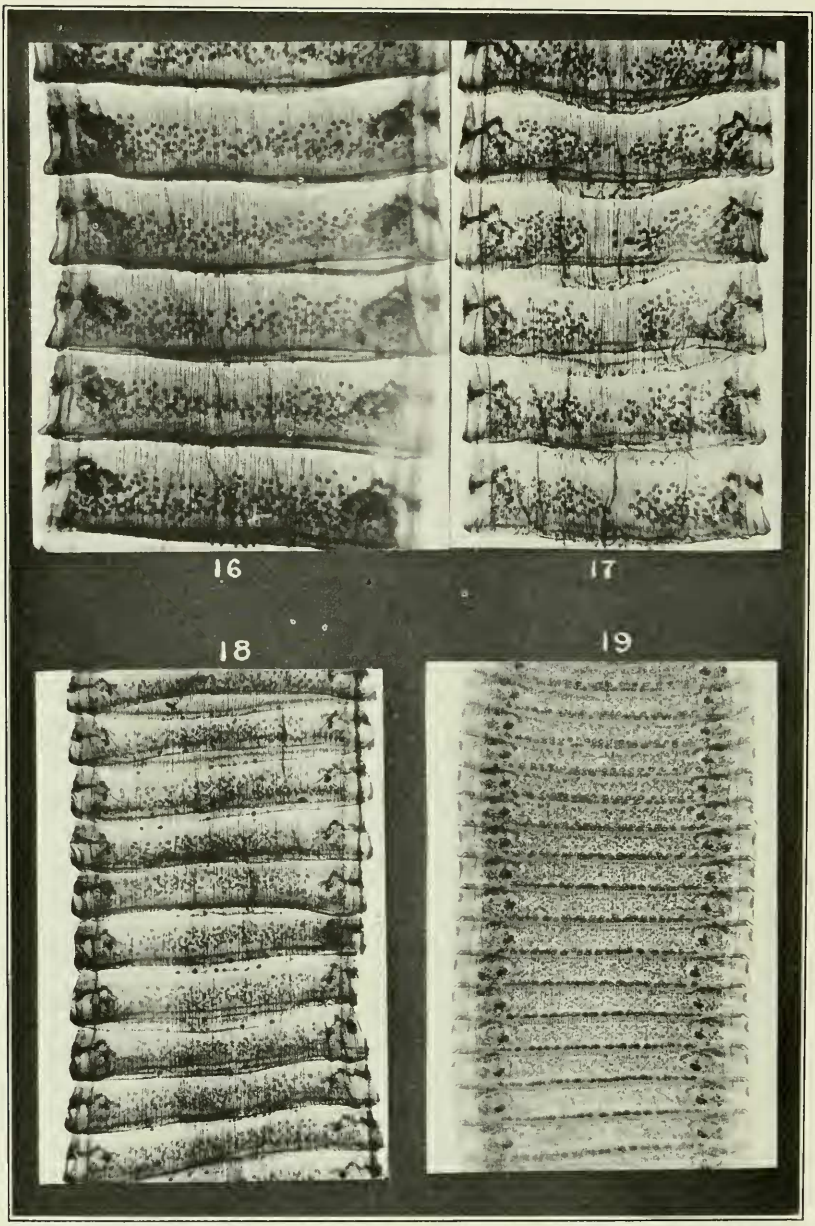
VARIATIONS IN MONIEZIA EXPANSA

FOR EXPLANATION OF PLATE SEE PAGE 9



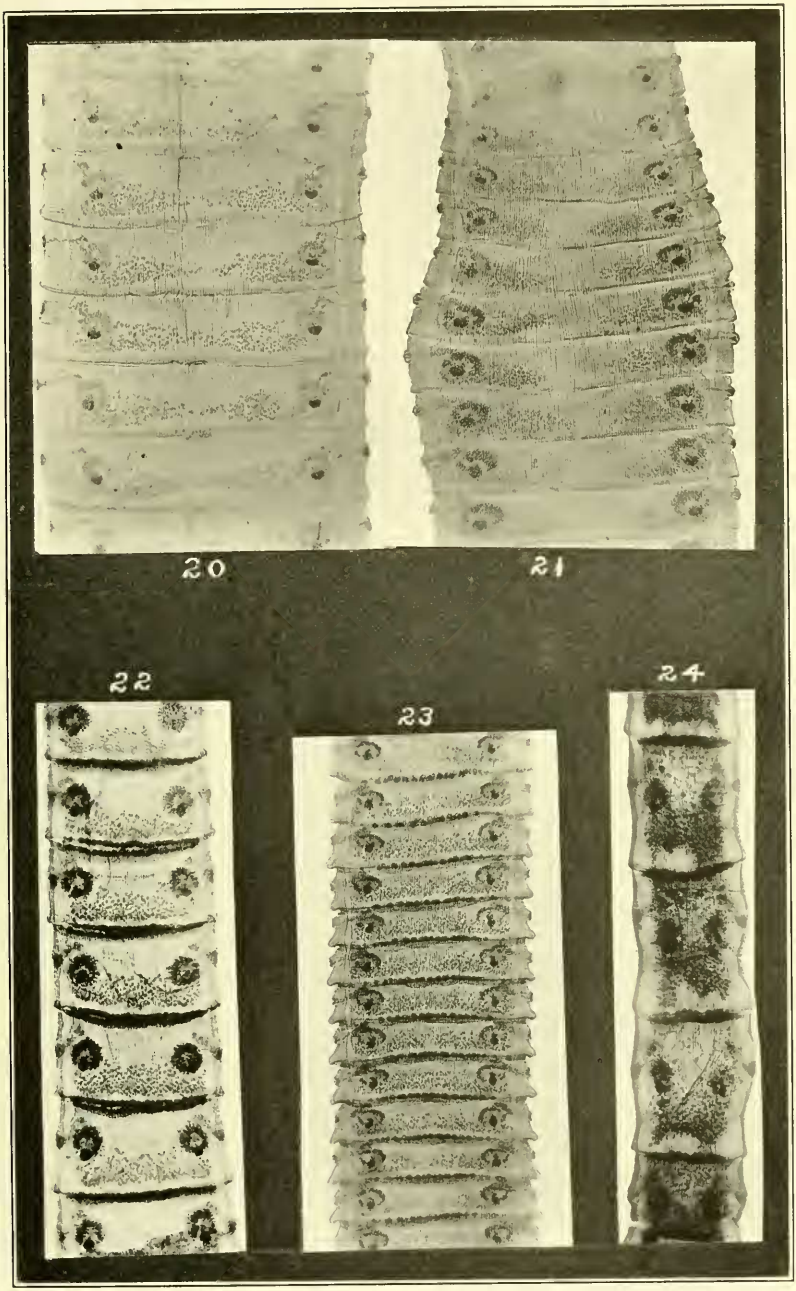
VARIATIONS IN MONIEZIA EXPANSA AND M. PLANISSIMA

FOR EXPLANATION OF PLATE SEE PAGE 9



VARIATIONS IN MONIEZIA EXPANSA

FOR EXPLANATION OF PLATE SEE PAGE 9



VARIATIONS IN MONIEZIA EXPANSA AND M. PLANISSIMA

FOR EXPLANATION OF PLATE SEE PAGE 9